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# STRENGTH OF NICKEL AND IRON FILMS OBTAINED BY VACUUM CONDENSATION

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ABSTRACT. Preparation of 20 ± 5-μ-thick nickel and iron films by vaporization in vacuum and deposition by condensation, at a rate of 0.2 - 0.3 μ/min, of metals of 99.99 and 99.9% purity, using a procedure of the authors described in previous papers. The tensile strength and microhardness of the films are measured and diagrammed. Nickel films, in contrast to copper and silver films, are found to exhibit a marked long-time stability at room temperature.

Previous work has been done with regard to the investigation of high strength properties of vacuum condensed copper, silver, and aluminum [1,2]. Research on the condensates of nickel and iron is of extreme interest, since the films of these metals and especially their alloys are finding wide use in modern technology, e.g., microelectronics, computers, et al. /310*

Vacuum condensates of nickel and iron which were 99.99 and 99.9% pure, respectively, were prepared according to the procedure outlined in [1,2]. The metals were condensed at a speed of about 0.2 - 0.3 μ/min, resulting in a film thickness, h, of 20 ± 5μ. The tensile strength and microhardness of the films were measured with the use of the PMT-3 automatic loading machine.

| $T_п$ °C | $H_μ$, kg/mm$^2$ | $c_B$, kg/mm$^2$ |
|---|---|---|
| 220 - 230 | 640 - 560 | |
| 250 - 270 | 500 - 400 | |
| 300 - 350 | 320 - 240 | < 66 |
| 400 - 420 | 260 - 240 | 66 - 74 |

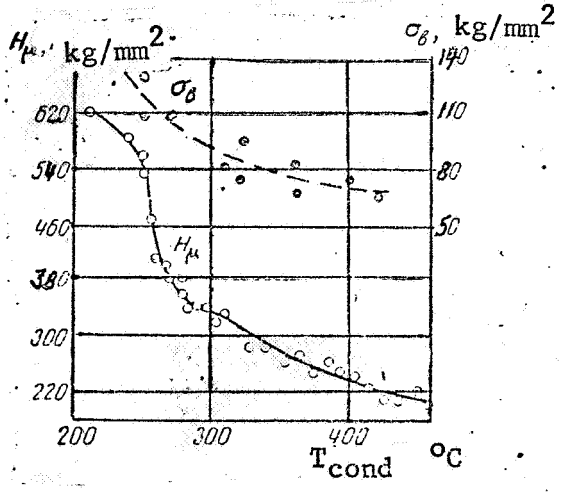


Fig. 1. Relationship of microhardness $H_μ$ and ultimate strength of nickel films to temperature of substrate during condensation.

*Numbers in the margin indicate pagination in the foreign text.

Basic results are given in Figs. 1,2 and in the table. As can be seen in Fig. 1, the condensates of Ni have the highest strength when they are prepared at reduced temperatures of the substrate $T_п$ . Thus when $T_п$ = 250 ÷ 210° C, their strength is: $H_μ$ = 540 - 620 kg/mm$^2$, $σ_B$ = 110 - 130 kg/mm$^2$, which exceeds by several times the corresponding values for solid annealed Ni (HB = 60-70 kg/mm$^2$, $σ_B$ = 33 kg/mm$^2$ [3]. When the temperature of the substrate is raised, a serese lowering of strength characteristics is observed, which slows down in the 280 - 300° region. The highest strength for solid Ni (strength of cold-rolled nickel strip HB = 160 kg/mm$^2$, $σ_B$ = 63 - 77 kg/mm$^2$ [3], is reached in films which are condensed at high temperatures (about 400 - 420°). /311

Fig. 2 depicts typical curves of tensile strength of Ni films, condensed at temperatures of about 250 and 350°. The character of the tensile curves shows a considerably effective blocking of the processes of movement and inception of dislocations. This corresponds to the general concepts of the high strength qualities of the condensed layers [1,2,4,5]. Similar regularities have been encountered when studying the condensates of Fe (See Table). The films of Fe had a matted surface, which led to the dispersion of values of $H_μ$.

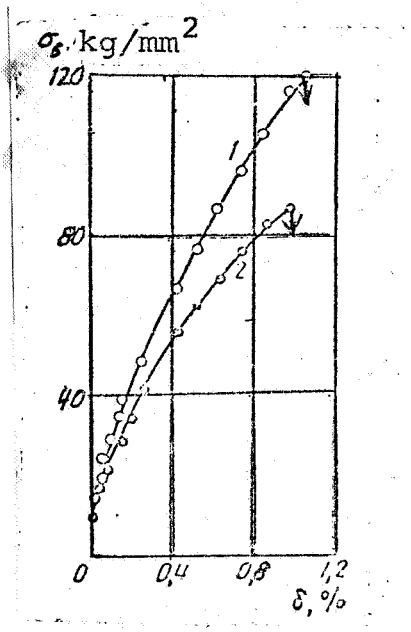


Figure 2. Curves of strength of Ni films (h = 15$_μ$): 1 - $T_п$ = 250°, $H_μ$ = 530 kg/mm$^2$; 2 - $T_п$ = 350°, H = 250 kg/mm$^2$.

The maximum values of the $H_μ$ for the Fe films approach those of hardened steel (for example, steel 40). An increase in $T_п$ causes lowering of the strength characteristics. Because of increased brittleness of the films of Fe, we were able to investigate the tensile strength of only high temperature samples. But even their strength ($H_μ$ = 240 - 260 kg/mm$^2$, $σ_B$ = 66 - 74 kg/mm$^2$) exceeds the corresponding values for solid annealed iron by several times (HB = 60 - 70, $σ_B$ = 18 - 25 kg/mm$^2$ [3] and approaches the strength of carbon steel.

In conclusion, we will note that the films of Ni, unlike those of Cu and Ag [1,2], are characterized by considerable stability of their strength qualities at room temperature, which is conditioned by a higher temperature of recrystallization. Thus, for example, retention of the films of Ni, of 20$_μ$ thickness, at room temperature for a period of 8 months does not lead to apparent changes of the strength characteristics.

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